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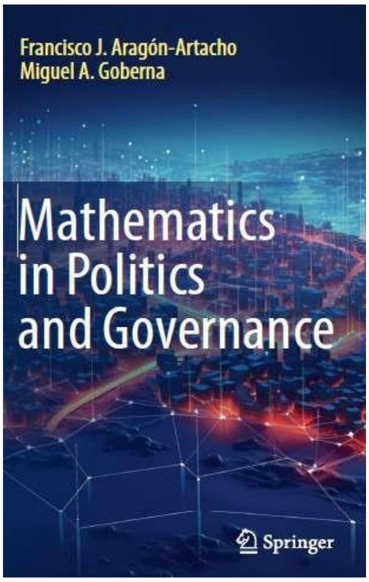

There are different ways to develop high school students' interest in mathematics, including posing intriguing problems (Engel, 2008), practicing creative activities as games and puzzles (Pound & Lee, 2022; Posamentier & Krulik, 2015), training geometric intuition (da Cruz Oliveira & Silva, 2024), or inserting in the curriculum activities related to real applications, for example, physics (Nahin, 2017) and engineering (Nahin, 2016, 2021). Aragón-Artacho and Goberna's book provides an outstanding collection of applications of mathematics to politics and governance, together with approximately 150 references providing the details and additional applications.

The book is divided into 6 chapters. The first five chapters show which mathematical tools are used often by politicians to make decisions about political and governance decisions that directly affect citizens. These chapters contain actual applications that can be used to develop interdisciplinary projects or create learning situations promoting acquisition of competencies by secondary students. Most of the topics addressed are based on the experiences reported by veteran politicians who have doctorate or master's degrees in mathematics, e.g., the former Prime Minister of Israel Ehud Barak (2018), the former Spanish Minister of Public Works and Foreign Affairs, the current High Representative of the European Union for Foreign Affairs and Security Policy, Josep Borrell (1992), and the former Portuguese Minister Nuno Crato (2019). The latter, Crato, also contributed to the book with a report on the way he used statistical tools to successfully reform the Portuguese education system. In turn, his German counterpart Johanna Wanka and her husband provided an interesting discussion on the known and potential applications of mathematics to political decision-making. The typical structure of each of these five chapters consists of an introduction to the topic of discussion with a transversal example involving a certain recruiting company for the U.S. Army,

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an informal introduction - supported by numerous figures - to the mathematical tools (concepts and numerical methods) that have been used, and finally, a selection of applications with real or simulated data (to simplify the presentation or because the real data are either secret or not publicly accessible). Interspersed boxes contain short biographies and higher-level comments.

Below, is a brief discussion on select applications found in Chapters 1-5, with a view toward their potential inclusion in the curriculum of high school mathematics.

Chapter 1: Mathematical Tools for Political Decision-Making

The comments (pp. 13-24) on the statistical lies of politicians (e.g., Nixon, Trump, Biden, López Obrador, Obama, and Bolsonaro, among others), of TV channels and of regulatory institutions (as those controlling the nuclear industry, whose risk of core meltdown turns out to be 25 times greater than that officially admitted) are intended to promote students' fact-checking activities. The data exhibited by politicians, media and nets can be compared with reliable data (as those of Eurostat) to detect statistical fake news.

The explanation (pp. 25-28) of the role played by game theory in the nuclear deterrent during the Cold War presents students the opportunity to play the role of decision-makers. Ehud Barak's failure to get a lasting peace agreement in the Middle East with the Palestinian leader Yasser Arafat in the 2000 Camp David Summit could serve as the basis of activities oriented to the mathematical arbitration of any type of conflict. .

Chapter 2: Feasibility (or How to Meet Requirements)

There is no point in teaching systems of linear equations without showing their applications. For example, linear systems are used to obtain the minima of quadratic functions, such as those arising in least squares regression and physics (Aragón, Goberna et al., 2019; Nahin, 2016, 2021). However, my favorite application of linear systems appears in this chapter and deals with the planning of economic growth. The exit from the Great Depression of 1929 is briefly discussed (pp. 62-65), a subject that has been covered in literature (Steinbeck's *The Grapes of Wrath*), cinema (the film of the same name by John Ford), history, economics, and mathematics. The mathematical model, proposed by the (not coincidentally) Russian economist Leontief, is a system of $n\times n$ linear equations whose coefficients are calculated from official econometric data and whose unknowns are the production levels of the n different sectors of the economy (n=46 for Leontief, about 500 today). Since computers did not yet exist in 1929, Leontief turned to a colleague at MIT, who designed a mechanical calculator to solve 10×10 systems using Cramer's rule. This forced Leontief to group the 46 economic sectors into just 10. Fortunately, mathematicians came to his aid in the 1930s, proposing an iterative method for $n>10$ based on successive orthogonal projections on the hyperplanes (which are easily calculated) represented by the n equations. The first proof of convergence (for a particular case) is due to the great mathematician John von Neumann, but would not be suitable for secondary students. Students can solve such small linear systems exactly by Cramer's formula or by elimination, or get an approximate solution by successive projections.

Just as the study of linear systems goes hand in hand with their solution sets, the linear manifolds, the study of systems of linear inequalities (currently absent in the high school curriculum) should go hand-in-hand with polyhedra. Two dimensional polyhedra (pp. 47- 49) arise in a natural way in health care (e.g., to fight against epidemics or assigning patients to hospitals) and citizen mobility (e.g., design of underground lines preserving monuments). Students can draw these plane polyhedra on the map by hand, with the help of a ruler and compass. The Fourier elimination method for systems of linear inequalities (slightly more difficult than the Gauss method for equations) allows small systems to be solved by hand, while large systems require iterative methods, such as alternating projection ones. On pp. 67-70, it is shown how the Pentagon dealt with its logistic decisions until 1945 by solving linear inequality systems making use of mechanical calculators.

Chapter 3: Scalar Optimization (or How to Make the Best Decision)

Scalar Optimization shows how in 1946 George Dantzig conceived a method to plan the Pentagon's logistics by minimizing linear functions on polyhedra, a type of optimization problem that can easily be solved when the functions are sufficiently small Linear programming is part of the Spanish curriculum of secondary students oriented to the social sciences. Also discussed is how Dantzig's group arranged in late 1949 for the Pentagon to fund the development of electronic computers in order to improve economic planning. It makes sense to discuss with the secondary students the dubious fundamentals of marginalist pricing, in particular that of the electricity markets.

A second topic of particular interest in this chapter is the optimization of functions of one variable, the best-known application of which is to physics in the obtaining of the optics laws by Fermat, who justified and corrected those derived by Descartes (see, e.g., Aragón, Goberna et al., 2019, pp. 41-43). No less interesting is the application of Newton's method to health policy decisions dealing with pandemics, such as the recent Covid-19 epidemic, by using the popular SIR model (pp. 94-98).

Chapter 4: Vector Optimization (or How to Make Insurmountable Decisions)

It is not difficult to understand the concept of efficient and weakly efficient solutions to vector optimization problems. These solutions can easily be graphically identified when there are only two objective functions. This was the case with the successful search for the Spanish vessel La Mercedes by the treasure hunting firm Odyssey Marine. La Mercedes was sunk in waters deep in the Gulf of Cadiz by the British Navy in 1804.. After a long litigation that ended with the final ruling of the United States justice system in 2007, Odyssey had to deliver the Mercedes' valuable cargo to the Spanish Government. The account of the location of the wreck (pp. 119-122) is, in my opinion, an excellent example of the cooperation of mathematicians with other professionals in interdisciplinary projects.

Also interesting is Crato's account (pp. 124-126) of how he managed to construct, using simple statistical techniques, a composite index that would allow a reasonable allocation of Portuguese teachers to schools by making the merits accumulated by teachers compatible with the schools' educational projects.

Chapter 5: Big Data (or How to Decide Using Massive Information)

Big Data is focused on the applications of machine learning, whose kernel is the separation of sets by hyperplanes, when it is possible or an approximate separation when it is not. The cases discussed in the book involve health care (automatic diagnosis), economics (detection of bankruptcy), political science (assignment of the authorship of *The Federalist Papers*), and forensic linguistics (identification of the persons behind the QAnon pseudonym).

Interesting and important instruction can be based on the mathematics underlying the exposure of dishonest tactics like diverting votes by powerful consulting firms (e.g., Cambridge Analytica-Facebook, pp. 161-165) and gerrymandering, where some legislators manipulate electoral districts to favor their parties. The authors show (pp. 167- 168) how courts fight against gerrymandering by using a roundedness index for the districts based on the isoperimetric theorem (pp. 39-42).

Chapter 6: The Impact of Political Decisions on Mathematics

This last chapter inverts the perspective of the previous chapters. The impact of significant political decisions on the development of mathematics in a selection of communities and countries is a subject likely more interesting for math teachers than for their students. Some notable examples include the following: the golden years of Russian mathematics in the 1960s despite the Stalinist purges; the abolition of Jewish ghettos after the French Revolution that triggered an explosion of talent in Germany and Italy; the rise of Hungarian mathematicians; the creation of a failed structuralist-inspired mathematical program by U.S. authorities in response to the Soviet victory with Sputnik in the 1960s; the exile of numerous mathematicians by Latin American dictatorships in the 1970s; and political interference in mathematics by racial and gender discrimination on the part of Turkish officials.

In summary, secondary math teachers will find many resources in this book to increase their students' interest in the applications of mathematics in the real world, particularly in politics and governance.

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About the Reviewer

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